Exchange Rate Volatility and Trade Flows: Taiwan Case

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Abstract of Thesis Entitled:

The exchange rate movements have been characterized by a high degree of variability since the collapse of the Bretton Woods agreement in 1973. It has long been argued that the exchange rate volatility would depress trade, but no consensus has been made until now. This thesis intends to investigate the impact of exchange rate volatility on trade by examining the case of Taiwan over the period 1982Q2 to 1997Q3. As well as Taiwan's multilateral trade flows, bilateral trade flows between Taiwan and its largest trading partner (the United States) are also examined. An autoregressive conditional heteroskedastic (ARCH) model is used to obtain the proxy for exchange rate volatility. Besides, the econometric techniques of Johansen maximum likelihood approach and error-correction modeling are applied to analyze the dynamic structure of the models. From the Johansen cointegration tests, the presence of the long-run equilibrium relationship among the variables is found in all cases. Based on the error-correction framework, we find that exchange rate volatility has a statistically significant impact on Taiwan's trade flows. For the investigation of multilateral trade flows, the findings are consistent that exchange rate variability exerts significantly negative effects on both export and import flows of Taiwan. In contrast, inconclusive results are yielded in the bilateral analysis.

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摘要

自 1973 年布列頓森林協定崩潰以來，匯率的波動情形開始有了巨幅的變化。長久以來，匯率波動是否會使得貿易衰退，一直爲人所爭議。然而，至今仍無法達成一致的共識。而本文的研究目的乃探討匯率波動對貿易的衝擊，並以台灣爲其研究對象，研究期間爲 1982 年第二季至 1997 年第三季。除了分析台灣的多邊貿易外，本研究並針對台灣與其最主要貿易國（美國）之間的雙邊貿易進行研究及探討。另外，本研究利用 ARCH 模型以取得匯率波動的因子；再者，本文的實證方法主要乃採用 Johansen 最大概似估計法與誤差修正模型等計量方法以分析模型的動態結構。從 Johansen 共整合分析結果顯示，我們發現變數之間都存在有長期的均衡關係。並基於誤差修正模型架構，我們發現匯率的波動是會對台灣的貿易有著顯著的影響。其中，對於多邊貿易的研究，我們發現匯率變動會對台灣的進口與及出口兩者都有著顯著的負面影響。相較之下，雙邊貿易的分析卻有著較不確定的結果。

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CHAPTER 1

INTRODUCTION

Since the breakdown of the Bretton Woods agreement in the spring of 1973, plenty of the world's trading nations have adopted freely floating exchange rates. This transition from fixed to flexible exchange rate regime has been supported by a number of economists, policy makers and financial market participants. However, the exchange rate movements have been characterized by a high degree of volatility after the inception of floating exchange rates, leading people to concern about the effects of exchange rate variability on the real economy, especially the impact on international trade. Voluminous theoretical and empirical studies have investigated this issue. Nevertheless, the results have been ambiguous and inconclusive.

As exchange rate risk will impose costs on risk-adverse individuals, they will generally reduce their participation in risky activities. There is a widespread belief that exchange rate volatility acts as an impediment to trade. Most of the early theoretical literature supports this common hypothesis (see for example, Ethier (1973) and Clark (1973)). On the other hand, recent theoretical studies, such as De Grauwe (1988) and Franke (1991), have established models to illustrate that the exchange rate variability may not exert negative influence on trade. De Grauwe (1988) analyzes the decisions of the traders by developing a theoretical model. He mentions that the effects of exchange rate risk on trade depend on the degree of risk aversion of the market participants. For the very risk-adverse traders, a rise in exchange rate volatility will increase the expected marginal utility of revenue and lead to a higher level of trade. Franke (1991) has also provided evidence in support of the positive impact of exchange rate variability on trade by analyzing the strategy of an exporting firm. He finds that any firm will enter sooner and exit later due to the increase in exchange rate variability. Hence, the average number of firms will consequently rise.

On the empirical front, the findings have also been limited significant and conflicting. A huge body of studies, such as Akhtar and Hilton (1984), Chowdhury (1993), Caporale and Doroodian (1994) and Arize (1997), support the adverse impact of variability of exchange rate. In contrast, other numerous studies offer empirical evidence that exchange rate volatility may exert a positive impact on trade, for example, Bailey, Tavlas and Ulan (1986), Klein (1990), Asseery and Peel (1991), McKenzie and Brooks (1997) and Daly (1998). In fact, the lack of consistent empirical results may be due to various estimation issues.

One of these issues is that most of the previous studies have not considered the nonstationarity of the variables employed in estimation. Indeed, Asseery and Peel (1991) state that " . . . Neglect of this point implies that the inferences made concerning income and price elasticities as well as that of the impact of exchange rate volatility on exports are potentially highly misleading . . . ". This study also considers this estimation problem and uses unit root test to examine the stationarity of the variables.

Besides, finding the appropriate measure of exchange rate volatility is another estimation problem. Various measures of exchange rate variability have been adopted in previous studies, namely, the moving standard deviations, the absolute percentage changes and the squared residuals of the ARIMA model. However, the main weakness of these measures is that they generally ignore the information of the stochastic process in the generation of the exchange rate. The autoregressive conditional heteroskedastic (ARCH) model proposed by Engle (1982) can complete the above task. In recent years, the ARCH model and its various extensions have become a popular approach to measure volatility of financial time series. In this thesis, we also apply the ARCH technique to generate the proxy for exchange rate variability.

Apart from the above estimation problems, Arize (1997) mentions that the conflicting findings may also be due to the failure of previous studies to account for the dynamic structure of the models employed. This thesis pays special attention to this problem. The econometric techniques of multivariate cointegration and error-correction modeling are applied to analyze the dynamic relationship among the variables. Currently, these econometric techniques have been well applied in the study of the effects of exchange rate volatility on trade (see for example, Chowdhury (1993), Arize (1997) and Arize and Shwiff (1998)).

In general, most of the previous studies have provided empirical evidence for the developed countries, such as the United States, Japan, West Germany, the United Kingdom, Canada, Italy and France. Relatively little work has been done to investigate the cases of the Asian countries. This study attempts to provide additional empirical evidence by investigating the influence of exchange rate volatility on the trade flows of Taiwan --- one of the largest traders in the Asia.

Taiwan is an island with a land area of 36,000 square kilometers and has a population of 21 million. With the rapid economic growth during the past four decades, Taiwan has been one of the major economic and trade powers in the world. The remarkable achievement of Taiwan's economy has been known as an "economic miracle". According to the Directorate-General of Budget, Accounting and Statistics, Executive Yuan, the Republic of China, Taiwan was the world's 18th-largest economy in 1997. In 1999, Taiwan's gross national product (GNP) reached as high as US$290.8 billion.

Similar to other small open economies, Taiwan is lack of land space and natural resources. Trade serves as the engine of Taiwan's economic development. Taiwan has been very successful in carrying out the strategy of trade orientation. According to the Ministry of Economic Affairs, the Republic of China, Taiwan's trade volume reached a peak of US$236.5 billion in 1997, ranked the 14th-largest trader in the world. Since then the trade figure has dropped back to US$232.3 billion in 1999. As one of the largest traders both in the world and Asia, international trade plays an important role in Taiwan's economy and the case of Taiwan is well worth to be studied.

As stated by McKenzie (1998), the implicit assumption of the uniform influence of exchange rate variability between countries and commodities may not correct, and the investigation of the aggregate data may weaken the true relationship between exchange rate volatility and trade. Hence, as well as multilateral trade flows, this study also analyzes Taiwan's bilateral trade flows. In this thesis, the bilateral trade between Taiwan and the United States is investigated because the United States is the largest trading partner of Taiwan. Since the early 1950s, the United States has maintained a mutually beneficial trade relationship with Taiwan. The bilateral trade of Taiwan with the United States makes up the largest proportion of Taiwan's total trade. In 1999, Taiwan's bilateral trade with the United States reached US$50.6 billion, occupied as high as 21.8 percent of Taiwan's total trade volume.

The organization of this thesis is as follows. Chapter two reviews the literature of the previous theoretical and empirical studies of the impact of exchange rate volatility on trade. In chapter three, the ARCH technique and estimation results of the proxy for exchange rate volatility are discussed. Chapter four introduces the econometric techniques of unit root test, structural change test, cointegration test and error-correction modeling. The specification of the models and description of the data employed in this study are presented in chapter five. Chapter six reports the empirical findings and analysis, while the last chapter is the conclusion.

CHAPTER 2

LITERATURE REVIEW

Many industrialized nations have adopted freely floating exchange rate regime since the collapse of the Bretton Woods system in early 1973. Contrary to the expectations of supporters of flexible exchange rate regime, this transition has been characterized by a high degree of volatility of exchange rates. One of the main concern since the introduction of the flexible exchange rate system is the impact of exchange rate volatility on international trade. Numerous theoretical and empirical studies have investigated the influence of exchange rate risk on trade. However, mixed results have been yielded.

2.1 Theoretical Contributions to the Literature

2.1.1 Negative Hypothesis

It is generally held that if there is a rise in risk, risk-adverse individuals or firms will reduce their participation in risky activities. When risk rises due to the more variability of exchange rate, uncertainty over potential profits will also increase. For risk-adverse traders, such an increase in profit risk may lead to a decline in revenue, and hence an adverse effect on the volume of trade. This common hypothesis is supported by most of the early theoretical studies. Ethier (1973) and Clark (1973) are two of the early theoretical contributions to the literature.

Assuming that the importing company knows its revenue for any value of exchange rate and its imports are denominated in foreign currency, Ethier (1973) theoretically models the decisions of a risk-adverse firm on both the import volume and the amount of forward cover in the exposure of exchange rate volatility. It is found that the level of trade is unaffected by exchange rate risk, but the amount of forward cover is affected. However, in reality, the importing firm may not possess such accurate profit information. In this situation, the uncertainty of the firm's profits increases the sensitivity of trade to exchange rate variability. Therefore, the author concludes that exchange rate risk will adversely affect the level of trade.

Clark (1973) also derives a similar model to analyze the impact of exchange rate uncertainty on the level of exports under both imperfect and perfect forward markets. This paper yields the same results as Ethier's paper that greater exchange rate risk will hamper the amount of trade.

Some recent theoretical work has also supported the common notion that exchange rate volatility depresses the volume of trade. For example, Wolf (1995) studies the level of imports and hedging decision of a risk-adverse importing firm. It is supposed that the firm faces two kinds of uncertainty, namely, exchange rate and import price uncertainty. In the presence of both of the two sources of uncertainty, the results show that the import demand and hedging is less than that simply under the uncertainty of exchange rate. In general, the author finds exchange rate uncertainty leads to a lower level of imports.

2.1.2 Positive Hypothesis

Although there are many theoretical studies supporting the negative hypothesis, some theoretical work has also suggested that exchange rate risk may actually lead to a greater level of trade, for instance, De Grauwe (1988) and Franke (1991).

De Grauwe (1988) investigates the influence of exchange rate variability by constructing a theoretical model about the decisions of the market participants. The only source of risk is the exchange rate risk. Moreover, assuming there is no capital market, traders cannot diversify the risk. The author states that a rise in exchange rate volatility will lead traders to increase or decrease the volume of trade, depending on the degree of risk aversion of traders. For the less risk-adverse market participants, an increase in exchange rate variability decreases the expected marginal utility of profits of trade. Hence, they will decrease foreign trade. On the other hand, for the very risk-adverse individuals, a rise in exchange rate volatility increases the expected marginal utility of revenue. This is because the very risk-averse traders will worry about the decline of the revenue due to an increase in exchange rate risk. Thus, they will raise the level of trade in order to avoid the possibility of a large decline in trade revenue. In contrast, the less risk-averse traders will not consider the worst possible outcome. They find the benefits from trade less attractive owing to a rise in exchange rate risk, and thus reduce the volume of trade.

Franke (1991) also supports the positive notion by analyzing the export strategy of a trading firm. The firm is assumed to be risk neutral. It gets profits by maximizing the net present value of export cash flows which is specified as an increasing function of real exchange rates. The decision of the entrance or exit of the firm from the foreign market depends on whether the present value of export cash flows is greater than that of the entry or exit cost. As the export cash flow function is convex in real exchange rates, the firm will benefit from a rise in exchange rate risk when the present value of export cash flows grows faster than the cost of entry or exit of the firm. Based on a variety of assumptions, when exchange rate risk increases, it is possible that the exporting firm will enter sooner and exit later. Since firms stay in the market for a longer time, the number of firms on average consequently rises. Therefore, exchange rate volatility will lead to a higher level of exports.

In a nutshell, extensive theoretical studies have been provided to analyze the effects of exchange rate risk on trade. Some models suggest that the variability of exchange rate depresses trade, while others predict the opposite results. In general, there is no common agreement about the influence of exchange rate volatility on trade.

2.2 Empirical Contributions to the Literature

As well as the theoretical contributions, a number of the empirical studies have also attempted to find out the relationship between exchange rate volatility and trade. However, the empirical results are also inconclusive. Many researchers have supported the common hypothesis that exchange rate risk depresses trade, for example, Akhtar and Hilton (1984), Cushman (1988) and Thursby and Thursby (1987). Nevertheless, the majority of their empirical results have been limited significant. Besides, other researchers have provided empirical evidence to support the opposite notion that increasing exchange rate volatility may not hamper trade, namely, Gotur (1985) and McKenzie and Brooks (1997).

Other than the empirical evidence, several issues that are relevant to the examination of the influence of exchange rate volatility on trade have also arisen. Some researchers claim that the inconclusive empirical results may be due to these issues, including the sort of trade examined, the estimation of exchange rate volatility, stationarity of variables, and methodology of estimation.

2.2.1 Investigation of Various Types of Trade Flows

To shed some light on the theoretical ambiguity over the impact of exchange rate risk on trade, numerous empirical studies have been produced. The relevant empirical analyses can be broadly divided into three types. One of the three types investigates the cases of multilateral trade flows, namely, Bailey, Tavlas and Ulan (1986), Chowdhury (1993) and Arize (1997). The other two types deal with the bilateral and sectoral trade flows (see for example, Hooper and Kohlhagen (1978), Cushman (1988), Klein (1990) and McKenzie (1998)).

2.2.1.1 Investigation of Multilateral Trade Flows

Bailey, Tavlas and Ulan (1986) analyze the effects of exchange rate volatility on the aggregate trade flows for each of the Big Seven OECD nations comprising of Canada, France, Germany, Italy, Japan, the United Kingdom and the United States over the period 1973 to 1984. The absolute percentage change of the nominal effective exchange rate is used as a proxy for the exchange rate volatility. However, the estimated coefficients illustrate that the impact of exchange rate risk on export volume is statistically insignificant. The authors conclude that the exchange rate volatility may exert a positive influence on trade.

A more recent empirical work by Chowdhury (1993) also examines cases of multilateral trade flows. By using the econometric technique of multivariate error-correction modeling and employing quarterly data series from 1973 to 1990, Chowdhury (1993) analyzes the relationship between the exchange rate risk and export volume of the G-7 countries. The empirical evidence supports the common notion and is statistically significant.

Similar to Chowdhury (1993), Arize (1997) employs the same estimation technique to analyze the impact of exchange rate uncertainty on export demand of seven industrialized countries, namely, Japan, Germany, Denmark, Italy, Switzerland, the United Kingdom and the United States. The results show that volatility of exchange rate exerts significantly negative effects on the export demand for all seven industrialized countries.

2.2.1.2 Investigation of Bilateral Trade Flows

Most of the previous studies have implicitly assumed that the impact of exchange rate risk is uniform across nations and various sectors of traded goods. However, McKenzie (1998) points out that this assumption may not correct in reality. Therefore, examining only the multilateral trade data would weaken the true relationship between exchange rate volatility and the level of trade. With this possibility in mind, several studies have investigated cases of bilateral and sectoral trade flows, instead of multilateral trade flows.

The work by Hooper and Kohlhagen (1978) is one of the earlier empirical studies on the impact of exchange rate risk on trade. By constructing the import demand and export supply model, Hooper and Kohlhagen (1978) examine the influence of exchange rate variability on both the price and volume of trade. Both the quarterly multilateral and bilateral trade data series of Canada, France, Germany, Japan, the United Kingdom and the United States from 1965 to 1975 are tested. For the analysis of multilateral trade flows, there is no statistically significant impact of exchange rate risk on trade prices and volume. The empirical results of the cases of bilateral trade reveal that there exists ambiguous relationship between exchange rate risk and trade prices and volume.

Both Cushman (1988) and Daly (1998) adopt the modification of the demand and supply model of Hooper and Kohlhagen (1978) to examine the cases of bilateral trade. Cushman (1988) investigates the bilateral trade flows of the United States from 1974 to 1983. He tries several types of estimation of exchange rate risk. The results demonstrate that exchange rate uncertainty exerts significantly negative effects on imports. In contrast, the results of impact on export flows are less conclusive. Only two out of six cases show that the influence of exchange rate risk is negative, and the impact is positive for one case.

Instead of the United States, Daly (1998) analyzes the bilateral trade flows of Japan over the period 1978 to 1992. Different from the work by Cushman (1988), Daly (1998) is concerned about the stationarity of the data series and the dynamic structure of the model. The empirical evidence reveals that the common hypothesis of the negative impact of exchange rate risk may not be held.

2.2.1.3 Investigation of Sectoral Trade Flows

Instead of bilateral trade data, some researchers even use more disaggregate trade data, such as sectoral trade data to examine the impact of exchange rate risk (see for example, Klein (1990) and McKenzie (1998)).

Klein (1990) investigates the effects of exchange rate uncertainty on exports by testing the sectoral export data series of the United States to seven industrialized countries include Canada, France, Japan, Germany, Italy and Netherlands. The sectoral export data is divided into nine categories of commodities. The empirical evidence illustrates that six out of the nine categories yield a statistically significant relationship, while five out of these six cases demonstrate the effects of exchange rate volatility are positive.

Similarly, McKenzie (1998) also examines the sectoral trade data. By analyzing both the aggregate and disaggregate trade data, he attempts to find out the effects of exchange rate volatility on trade flows of Australia over the period 1988 to 1995. The results of multilateral trade flows are ambiguous. Bilateral trade data is also tested, but additional significant results are not obtained. In contrast, the examination of sectoral trade data yields statistically significant results. The study finds that the exchange rate risk exerts a positive impact on Australian sectoral exports, while the influence on sectoral imports is negative. The author also states that the influence of exchange rate volatility is different across various sectors of traded commodities.

2.2.2 Estimation of Exchange Rate Volatility

In fact, the most problematic area in the research is the generation of the appropriate estimation of exchange rate volatility. With reference to previous work, the moving standard deviation or the variance of the observations has been one of the commonly used measures of exchange rate volatility (see for example, Akhtar and Hilton (1984), Cushman (1988), Koray and Lastrapes (1989), Klein (1990) and Chowdhury (1993)). This measure of exchange rate volatility is as shown in equation (2.1):

$$V_t = \left[(1/m) \sum_{i=1}^{m} (\log R_{t+i-1} - \log R_{t+i-2})^2 \right]^{1/2} \qquad (2.1)$$

where V is the volatility of real exchange rate, R is the real exchange rate and m is the order of moving average.

Other techniques of estimation of exchange rate volatility have also been adopted. For example, Bailey, Tavlas and Ulan (1986) measure the exchange rate volatility by the absolute value of the percentage change of the nominal effective exchange rate. The measure of exchange rate volatility used by Bailey, Tavlas and Ulan is as shown as follows.

$$V_t = | (E_t - E_{t-1}) / E_{t-1} | \qquad (2.2)$$

where V is the volatility of nominal effective exchange rate and E is the nominal effective exchange rate.

Hooper and Kohlhagen (1978) employ both the variances of spot and forward exchange rates and the average absolute difference between the previous forward rate and the current spot rate as proxies in order to find out which one is the best indicator of exchange rate variability.[1] Besides, Asseery and Peel (1991) adopt the squared residuals of the ARIMA model as a proxy for exchange rate risk.

[1] The average absolute difference between the previous forward rate and the current spot rate is defined as $V_t = \sum_{i=1}^{k} | F_{t-1} - S_t | / k$, where V is the volatility of exchange rate, F is the forward rate and S is the spot rate. Hooper and Kohlhagen (1978) state that "The major advantage of this variable, compared with the standard deviation of either the spot or the forward rate, is that under pegged but adjustable exchange rates it might better indicate the market's assessment of exchange risk during the

However, some researchers criticize the above techniques as inappropriate because they neglect the information of the stochastic process in the generation of the exchange rate. In fact, it is more appropriate for the exchange rate volatility estimator to be based on the estimation which centers on the prediction errors. Amongst various measures of exchange rate volatility, the autoregressive conditional heteroskedastic (ARCH) model proposed by Engle (1982) is an appropriate technique that can fulfill this task. Currently, ARCH model and its various extensions have become a popular technique to measure the volatility of exchange rate. For instance, Pozo (1992), Caporale and Doroodian (1994), McKenzie and Brooks (1997) and McKenzie (1998) also apply this technique to estimate exchange rate variability.

2.2.3 Stationarity of Variables

In fact, the lack of conclusive and significant empirical evidence may be due to some econometric problems, such as the ignorance of the nonstationarity of the data series. Actually, the presence of nonstationary variables in statistical models would potentially generate the problem of spurious regression.

Asseery and Peel (1991) criticize the previous studies for ignoring this estimation problem in the research. In their study, seasonally adjusted quarterly trade data is employed to test for the impact of exchange rate volatility on the export volume of five countries from 1972 to 1987. Asseery and Peel (1991) use Dickey

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period leading up to a parity change…".

Fuller (DF) and Augmented Dickey Fuller (ADF) tests to check for the stationarity of variables. By applying an error-correction framework, significant empirical results are obtained. It is found that the volatility of exchange rate leads to a higher level of exports, except for the case of the United Kingdom.

More recent studies have paid special attention to the nature of nonstationarity of the data series. Many of them use the Augmented Dickey Fuller (ADF) test to check for the stationarity of the data series employed (see for example, McKenzie and Brooks (1997) and Daly (1998)).

2.2.4 Methodology of Estimation

Despite the stationarity of regressors, another important issue relevant to the investigation of the impact of exchange rate volatility is the methodology of estimation. Amongst various estimation methodologies, the most popular method is the ordinary least squares (OLS) regression. Extensive empirical studies have used this technique to analyze the relationship between exchange rate volatility and trade, namely, Hooper and Kohlhagen (1978), Gotur (1985), Bailey, Tavlas and Ulan (1986), Cushman (1988), Akhtar and Hilton (1991), Thursby and Thursby (1987), and McKenzie and Brooks (1997). However, some economists claim that empirical work should pay more attention to the dynamic structure of models employed. More recent research adopts other approach, such as the vector autoregression (VAR) approach. For example, Koray and Lastrapes (1989) adopt the VAR approach in their study in which they point out several advantages of this approach such as there being no theoretical restrictions on variables. Moreover, this estimation method is able to accommodate general dynamic relations among variables.

Currently, empirical work tends to focus on capturing the dynamics of the trade equations. By adopting the multivariate cointegration technique, recent empirical studies construct the error-correction models in order to establish the long-run equilibrium relationship among the variables and the short-run disequilibrium behavior. For instance, Chowdhury (1993) and Arize (1997) both apply these estimation techniques in their studies.

CHAPTER 3

ESTIMATION OF EXCHANGE RATE VOLATILITY

Finding the appropriate measure of volatility of exchange rate has long been the most problematic area in the study of the effects of exchange rate variability on international trade. Various measures of exchange rate volatility have been adopted in previous literature. For instance, studies done by Akhtar and Hilton (1984), Cushman (1988), Koray and Lastrapes (1989), Klein (1990) and Chowdhury (1993) use the moving standard deviation of exchange rate as the proxy for variability of exchange rate, while Hooper and Kohlhagen (1978) measure exchange rate volatility as the absolute difference between forward and spot rates. Some studies also try other estimation techniques. For example, Bailey, Tavlas and Ulan (1986) estimate the exchange rate variability as the absolute percentage change of exchange rate and Asseery and Peel (1991) employ the squared residuals of the ARIMA model as a proxy.

However, it has long been argued that these measures of exchange rate volatility are not appropriate. Researchers like McKenzie and Brooks (1997) criticize the failure of these measures to account for the information of the stochastic process in the generation of the exchange rate. These estimation techniques are not able to capture the dynamic properties of the economic time series. In fact, majority of the financial time series, like the data series of exchange rates are heteroskedastic, leptokurtic and also characterized by volatility clustering in the distribution. Hence, researchers note that it would be more appropriate to model the volatility in the economic time series as conditional on the past realizations in order to capture the above characteristics.

In case, the autoregressive conditional heteroskedastic (ARCH) model can fulfill the above task. Since the introduction by Engle in 1982, autoregressive conditional heteroskedastic (ARCH) model and its various extensions have become a popular approach to capture the dynamic properties of the economic time series. Currently, an increasing number of empirical literature have applied this technique to estimate the proxy for variability of exchange rate, namely, Pozo (1992), Caporale and Doroodian (1994), McKenzie and Brooks (1997) and McKenzie (1998). Researchers claim that this technique is the most appropriate way to capture the volatility of exchange rate.

In this study, we also apply an autoregressive conditional heteroskedastic (ARCH) model to obtain the estimator of exchange rate volatility. The remainder of this chapter is presented as follows. The methodology of estimation of the ARCH model is discussed in the first section. Then, section two reports the estimation results of the exchange rate variability by employing the ARCH technique.

3.1 Methodology of Estimation of ARCH Model

It is generally assumed that the conditional and unconditional variances of the disturbance term of most economic time series are constant over time. However, with reference to many financial and economic applications, it is found that this assumption of the homoskedasticity is not true. Engle (1982) proposes a new econometric technique, the ARCH model, in order to model the heteroskedasticity of the economic time series.

Suppose an economic time series which is represented as an autoregression, and hence an ARMA model of order p is shown as equation (3.1).

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \ldots\ldots\ldots\ldots + \alpha_p y_{t-p} + \varepsilon_t \tag{3.1}$$

$$E[\varepsilon_t \mid \Omega_{t-1}] = 0 \tag{3.2}$$

$$Var[\varepsilon_t \mid \Omega_{t-1}] = h_t^2 \tag{3.3}$$

$$\varepsilon_t \mid \Omega_{t-1} \sim N(0, h_t^2) \tag{3.4}$$

where ε is the disturbance term, Ω_{t-1} is the information set available at time t.

As shown in equation (3.2) and (3.3), it is assumed conditional on the available information set, the error term has a mean value that is equal to zero and a time varying variance h_t^2. Equation (3.4) gives a more restrictive definition, which is often used. Besides, the time varying conditional variance h_t^2 is generated as an autoregressive conditional heteroskedastic (ARCH) process of qth order:

$$h_t^2 = \rho_0 + \rho_1 \varepsilon_{t-1}^2 + \rho_2 \varepsilon_{t-2}^2 + \ldots\ldots\ldots\ldots + \rho_q \varepsilon_{t-q}^2 \tag{3.5}$$

where $\rho_0 > 0$, $\rho_i \geq 0$, $i = 1, \ldots\ldots, q$.

As illustrated in equation (3.5), the error variance is conditional on the past variances of the disturbance terms. Equation (3.5) is known as the qth order autoregressive conditional heteroskedastic model, and hence an ARCH (q) model.

Bollerslev (1986) extends the work of Engle (1982) and develops a generalized version of ARCH (GARCH) model. For the GARCH model, the conditional variance of the disturbance term is presented as an autoregression, therefore ARMA process. As indicated in equation (3.6), the time changing conditional variance is illustrated as a GARCH (p, q) model.[2]

$$h_t^2 = \rho_0 + \sum_{i=1}^{q} \rho_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \phi_j h_{t-i}^2 \tag{3.6}$$

where $\rho_0 > 0$, $\rho_i \geq 0$, $i = 1,\ldots\ldots,q$ and $\phi_i \geq 0$, $j = 1,\ldots\ldots,p$.

The estimation of the ARCH or GARCH model involves two stages. The first stage is testing for the presence of the ARCH effects in the conditional variance of the disturbances. This is done by regressing the squares of the residuals on the constant and the past squared error terms, while the squares of residuals is obtained from the regression of an autoregression, hence an AR (p) model which is presented as in equation (3.1).

With reference to equation (3.5), the conditional variance evolves as an

[2] Instead of the basic ARCH and GARCH model, economists also develop a variety of extensions of ARCH model, such as exponential ARCH (EARCH) model, ARCH-M model and so on. However,

autoregressive conditional heteroskedastic (ARCH) process. Supposing there are no ARCH effects, the estimated values of the coefficients $\rho_1, \ldots\ldots, \rho_q$ should be zero. Hence, the null hypothesis is set as (3.7).

$$H_0 : \rho_1 = \rho_2 = \ldots\ldots\ldots = \rho_q = 0 \tag{3.7}$$

In contrast, the estimated values of the coefficients $\rho_1, \ldots\ldots, \rho_q$ would not be equal to zero if there are ARCH effects. Therefore, the alternative hypothesis is shown as follows.

$$H_1 : \rho_1 \neq 0, \rho_2 \neq 0, \ldots\ldots, \rho_q \neq 0 \tag{3.8}$$

Engle (1982) proposes the Lagrange Multiplier (LM) test to examine the presence of ARCH effects. Suppose the data series with T residuals, the statistic TR^2 converges to chi-square χ_q^2 distribution under the null hypothesis, where R^2 is the R^2 statistic of the regression of equation (3.5). If the TR^2 statistic does not exceed the 95% level, the null hypothesis cannot be rejected. In contrast, it can be concluded there are ARCH effects if this statistic is well above the critical value. After testing for the presence of ARCH effects, various ARCH models can be estimated in order to capture the time varying conditional variance.

3.2 Estimation Results of Real Effective Exchange Rate Volatility

In this study, an autoregressive conditional heteroskedastic (ARCH) model is

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we shall not discuss these models in details.

applied to estimate the volatility of exchange rate. Quarterly data series of real effective exchange rate index of Taiwan over the period 1980Q2 to 1999Q1 is extracted from the Taiwan Economic Journal Data Bank. The data of real effective exchange rate over the period 1980Q2 to 1997Q3 is estimated and the observations from 1997Q4 to 1999Q1 are kept for forecasting analysis. Real effective exchange rate is a multilateral real exchange rate.[3] In the construction of the index of real effective exchange rate, the trade weights of various trading partners with Taiwan are also included in the calculation. Hence, real effective exchange rate can offer a measure of degree of competitiveness of Taiwan relative to various trading partners.

Before estimating the ARCH model for capturing the conditional variance of real effective exchange rate, it is necessary to test for the presence of the ARCH effects in the conditional variance which evolves as an ARCH process, therefore as a function of past squared disturbance terms as shown in equation (3.5).

By employing the raw data of real effective exchange rate, the most

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[3] As stated in chapter four of *Real Exchange Rates Devaluation and Adjustment: Exchange Rate Policy in Developing Countries,* the index of real effective exchange rate is defined as follows:

$MRER_{jt} = \dfrac{\sum_{i=1}^{k} \alpha_i E_{it} P_{it}^{*}}{P_{jt}}$, where $MRER_{jt}$ is the index of multilateral real exchange rate in period t for country j; E_{it} is the index of nominal exchange rate between country i and country j in period t; $i = 1, \ldots\ldots, k$ refers to the k partner countries used in the construction of index of real effective exchange rate; α_i is the weight corresponding to partner i in the computation of $MRER_{jt}$; P_{jt} is the price index of the home country and P_{it}^{*} is the price index of partner country i in period t. Besides, the index of real effective exchange rate is computed in terms of geometrical weighted average and is defined as $MRER_{jt} = \prod_{i=1}^{k} \left(\dfrac{E_{it} P_{it}^{*}}{P_{jt}}\right)^{\alpha_i}$ in Taiwan.

appropriate autoregression, AR (8) model is estimated by ordinary least squares that is represented in equation (3.9).

$$RE_t = \alpha_0 + \alpha_1 RE_{t-1} + \dots\dots\dots + \alpha_8 RE_{t-8} + \varepsilon_t \tag{3.9}$$

where RE is the real effective exchange rate and ε_t is the error term at time t.

The squares of the residuals are obtained. Then, the squared residuals are regressed on the constant and the past squared error terms. Test results for the ARCH effects in the form of the Lagrange Multiplier (LM) statistics proposed by Engle (1982) are yielded. Table 1 reports the estimated Engle's LM statistics that are calculated with a lag length of one to four.

Table 1 Test Results for the ARCH Effects

Lags	LM Statistics
1	6.6343 (0.010) **
2	7.3630 (0.025) **
3	7.3791 (0.061) *
4	8.6483 (0.071) *

Note: An asterisk (*) and a double asterisk (**) indicate the statistical significance at the 10% and 5% levels respectively. Figures in parentheses are p-values.

The LM statistic that is calculated with a lag length of one is 6.6343, which exceeds the 95 percent confidence intervals of chi-square distribution χ_1^2. Therefore, the null hypothesis of no ARCH effects is rejected. Tests for higher order of lag length also offer similar significant results. Hence, these results illustrate the presence of significant ARCH effects in the conditional variance of disturbances.

Then, an ARCH (1) or GARCH (0, 1) model is estimated to capture the time varying conditional variance of the real effective exchange rate, which is shown in equation (3.10).

$$h_t^2 = \underset{(13.33)}{0.0002} + \underset{(1.75)}{0.4176}\varepsilon_{t-1}^2 \tag{3.10}$$

The t-statistics of the estimated coefficient of ε_{t-1}^2 and the constant shown in the parentheses are statistically significant at the 90 percent and 95 percent confidence intervals respectively. The conditional variance by computing the above ARCH (1) model is used as a proxy for the volatility of real effective exchange rate in this study. Other higher order ARCH, GARCH models and various extensions of the ARCH framework have also been tried, but all these trials are not successful.

CHAPTER 4

METHODOLOGY OF EMPIRICAL ANALYSIS

For the empirical analysis, this study aims to investigate the effects of exchange rate volatility on trade flows of Taiwan. The analysis is based on the error-correction framework, the maximum likelihood cointegration procedure developed by Johansen (1991) is also applied. Before the Johansen cointegration analysis, it is necessary to test for the order of integration of all variables by applying the unit root test. In this study, two types of unit root test are performed, namely, the augmented Dickey-Fuller (ADF) test and Phillips and Perron (P-P) test. Besides, it is also important to examine for the structural break for both the unit root test and cointegration analysis. The test proposed by Zivot and Andrews (1992) is used to complete this task. In the following sections, the econometric methodology of the ADF test and P-P test is presented first. Section two discusses the ZA test. Then, the econometric techniques of the Johansen (1991) maximum likelihood approach and error-correction modeling are introduced in section three.

4.1 Unit Root Test

For the Johansen (1991) maximum likelihood approach, an important procedure involves testing for the order of integration of the variables. Theoretically, the variables are possibly cointegrated if they are integrated of the same order. In this study, the augmented Dickey-Fuller (ADF) test and

Phillips-Perron (P-P) test are performed to examine for the order of integration of the variables. The estimation technique of the ADF test is introduced first.

4.1.1 Augmented Dickey-Fuller (ADF) Test

Dickey and Fuller (1979, 1981) propose the augmented Dickey-Fuller (ADF) test. As mentioned in section 2.2.3 of chapter two, plenty of empirical studies on the impact of exchange rate volatility have also used the ADF test to check the stationarity of variables. The basic concept of the ADF test is illustrated as follows.

In this study, the ADF test considers two regression equations of a time series y_t as indicated in equation (4.1) and (4.2).

$$\Delta y_t = \rho_0 + \rho_1 y_{t-1} + \sum_{i=2}^{p} \phi_i \Delta y_{t-i+1} + \varepsilon_t \tag{4.1}$$

$$\Delta y_t = \rho_0 + \rho_1 y_{t-1} + \rho_2 t + \sum_{i=2}^{p} \phi_i \Delta y_{t-i+1} + \varepsilon_t \tag{4.2}$$

where the disturbance term ε_t is assumed to be white noise and t is a linear time trend that t = 1,2,.....,T.

Equation (4.1) includes an intercept, while equation (4.2) contains an intercept and a time trend. To test for the presence of a unit root, the null hypothesis is set as $\rho_1 = 0$, while the alternative hypothesis is $\rho_1 < 0$. By using the OLS to estimate the above two equations, the estimated value and the standard error of ρ_1 are obtained. Then, the resulted t-statistic of ρ_1 is compared with those of the critical values reported by Dickey and Fuller. If the t-statistic exceeds the critical values, it is concluded that the data series is stationary. Also, the order of the lagged terms is set in order to ensure that the disturbance terms have constant variance and are uncorrelated. The order of lagged terms is chosen according to the Schwarz Bayesian Criterion (SBC).[4]

4.1.2 Phillips-Perron (P-P) Test

Instead of the augmented Dickey-Fuller (ADF) test, the Phillips-Perron (P-P) test developed by Phillips and Perron (1988) is also performed to examine for the order of integration of the variables. When comparing these two types of unit root test, the main difference between them is the assumption imposed by the P-P test on the distribution of the disturbance terms is weaker. For the P-P test, the disturbance terms are permitted to be weakly dependent and heterogeneously distributed. In contrast, the ADF test imposes a more restrictive assumption that the errors are homogeneously distributed and independent.

Similar to the ADF test, the estimation procedure of the P-P test is also started by estimating the regression equations as illustrated in equation (4.1) and (4.2). However, the order of the lagged terms is set at zero. Besides, the test statistics of the P-P test are the modifications of the test statistics of the ADF test by

[4] In this study, the lag adjusted critical values provided by Cheung and Lai (1995) are employed for the ADF test.

concerning the weaker assumption on the distribution of disturbance terms.[5]

4.2 Zivot and Andrews (ZA) Test

With reference to Enders (1995), various unit root tests would have a bias towards the non-rejection of a unit root in the presence of the structural change. Moreover, the cointegration test would be in favor of no cointegrating relationship exists among the variables if the existence of the structural change is omitted in the analysis. Hence, testing for the presence of structural break is also an important step in the cointegration analysis.

In this empirical analysis, the test proposed by Zivot and Andrews (1992) is performed. Zivot and Andrews (1992) transform the unit root test of Perron (1989) which tests for a unit root in the presence of structural change at a known point of time. Following the testing strategy of unit root test of Perron (1989), the test of Zivot and Andrews (ZA) considers the following three regression equations which test for a unit root with the structural break occurs at an unknown point in time.

$$y_t = \hat{\mu}^A + \hat{\theta}^A DU_t(\hat{\lambda}) + \hat{\beta}^A t + \hat{\alpha}^A y_{t-1} + \sum_{j=1}^{m} \hat{c}_j^A \Delta y_{t-j} + \hat{e}_t \tag{4.3}$$

[5] The critical values used for the Phillips-Perron (P-P) test are the same as those employed for the augmented Dickey-Fuller (ADF) test.

$$y_t = \hat{\mu}^B + \hat{\beta}^B t + \hat{\gamma}^B DT_t^*(\hat{\lambda}) + \hat{\alpha}^B y_{t-1} + \sum_{j=1}^{m} \hat{c}_j^B \Delta y_{t-j} + \hat{e}_t \tag{4.4}$$

$$y_t = \hat{\mu}^C + \hat{\theta}^C DU_t(\hat{\lambda}) + \hat{\beta}^C t + \hat{\gamma}^C DT_t^*(\hat{\lambda}) + \hat{\alpha}^C y_{t-1} + \sum_{j=1}^{m} \hat{c}_j^C \Delta y_{t-j} + \hat{e}_t \tag{4.5}$$

where $DU_t(\lambda) = 1$ if $t > T\lambda$, and $DU_t(\lambda) = 0$ otherwise; $DT_t^*(\lambda) = t - T\lambda$ if $t > T\lambda$, and $DT_t^*(\lambda) = 0$ otherwise; λ is the break fraction that $\lambda = \frac{T_B}{T}$ and T_B is the breakpoint in time.

The first regression equation illustrates a "crash" model which permits a one time change in the level of the data series, while the second equation shows a "changing growth" model that a one time change in the slope of the trend function is permitted in that model. The third regression equation represents a model that consists of both of the changes in the level and the slope of the trend function of the data series. The null hypothesis of a unit root is as shown in equation (4.6):

$$y_t = \mu + y_{t-1} + \varepsilon_t \tag{4.6}$$

The estimation scheme of the ZA test is consistent with the unit root test of Perron (1989), that is, choosing the breakpoint which offers the least favorable results for the null hypothesis as demonstrated in equation (4.6). To test for the presence of the structural break, the break fraction λ is selected to minimize the one-sided test statistic for testing $\alpha^i = 1$, where $i = A, B, C$. The t-statistic is defined as follows.

$$t_{\hat{\alpha}^i}\left[\hat{\lambda}^i_{\inf}\right] = \inf_{\lambda\in\Lambda} t_{\hat{\alpha}^i}(\lambda) \tag{4.7}$$

where $\hat{\lambda}^i_{\inf}$ stands for the minimizing value for model i, that $i = A, B, C$ and Λ is a specified closed subset of $(0,1)$. The null hypothesis is rejected if

$$\inf_{\lambda\in\Lambda} t_{\hat{\alpha}^i}(\lambda) < \kappa^i_{\inf,\alpha} \tag{4.8}$$

where $\kappa^i_{\inf,\alpha}$ represents the size α left-tail critical value from the asymptotic distribution of $\inf_{\lambda\in\Lambda} t_{\hat{\alpha}^i}(\lambda)$.

To determine the breakpoints and minimum test statistics, equation (4.3), (4.4) and (4.5) are firstly estimated by the OLS with the break fraction λ, ranging from $\frac{2}{T}$ to $\frac{T-1}{T}$. Furthermore, the test statistic for testing $\alpha^i = 1$ is computed for each value of the break fraction. The minimum test statistic is the smallest among all of the T-2 regressions, while the breakpoints are the points in time corresponding to the minimum test statistic.[6]

4.3 Cointegration and Error-Correction Mechanism

The relationship between cointegration and error-correction model has been studied by a number of econometricians, such as Engle and Granger (1987), Johansen and Juselius (1990) and Johansen (1991).

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[6] The critical values of the ZA test are provided by Zivot and Andrews (1992).

4.3.1 Concept of Cointegration

Engle and Granger (1987) propose the formal concept of cointegration. To conduct the analysis, Engle and Granger (1987) primarily suggest considering a set of variables $x_t = (x_{1t}, x_{2t}, ... x_{nt})'$, where x_t represents a vector. The whole system is in the long-run equilibrium when $\beta_1 x_{1t} + \beta_2 x_{2t} + ... + \beta_n x_{nt} = 0$, or represented as $\beta x_t = 0$, where β represents a vector that $\beta = (\beta_1, \beta_2, ..., \beta_n)$. The deviation from the long-run equilibrium is denoted by the equilibrium error e_t, where $e_t = \beta x_t$. The long-run equilibrium is meaningful only if this equilibrium error process is stationary.

According to Engle and Granger (1987), the definition of cointegration is presented as follows. Suppose all elements of vector x_t are integrated of order d. Also, there exists another vector $\beta = (\beta_1, \beta_2, ..., \beta_n)$ that the combination βx_t has the order of integration (d-b), where b>0. If the above two conditions are satisfied, the elements of vector x_t are said to be cointegrated of order d, b, and represented as $x_t \sim CI(d,b)$. The vector β is known as the cointegrating vector.

4.3.2 Cointegration Test and Error-Correction Model

Before establishing the error-correction model, it is necessary to test for the cointegration among the variables. There are two cointegration approaches that are commonly used in empirical literature, namely, the residual-based approach of Engle and Granger (1987) and Johansen (1991) maximum likelihood approach.

The procedure of Engle-Granger residual-based cointegration approach involves several steps. Suppose there are two data series x_t and y_t. After testing for the order of integration of these two variables, the long-run equilibrium relationship $y_t = \alpha_0 + \alpha_1 x_t + \varepsilon_t$ is estimated by OLS. Then, the stationarity of the residuals from the above regression equation is tested. If the residuals are stationary, that means the variables are actually cointegrated and the residuals can be employed to estimate the error-correction model. According to the Granger Representation Theorem developed by Engle and Granger (1987), there exists an error-correction model that is appropriate for all the cointegrated variables.

However, with reference to Enders (1995), there are some shortcomings for the testing procedure of Engle-Granger residual-based cointegration approach. The main shortcoming is that the test for cointegration of this approach is not invariant to the choice of the variable selected for normalization. Also, this cointegration approach has no systematic procedure to estimate for the multiple cointegrating vectors. These problems can be avoided by employing other methods, such as the Johansen (1991) maximum likelihood procedure. For this approach, the estimated long-run equilibrium result is invariant to the choice of the variable chosen for normalization. Also, the presence for multiple cointegrating vectors can also be estimated. Due to the defects of Engle-Granger residual-based approach, the Johansen maximum likelihood approach is used to test for cointegration in this empirical analysis. The followings will illustrate the Johansen maximum likelihood approach.

The Johansen (1991) maximum likelihood procedure involves several stages. Before testing for the cointegration among the variables, it is necessary to test for the order of integration of the variables. In this study, the ADF test and P-P test are applied. For the testing procedure, the determination of a lag length for the vector autoregression (VAR) model is required. The VAR model to be estimated is as illustrated in equation (4.9).

$$x_t = \pi_0 + \pi_1 x_{t-1} + \pi_2 x_{t-2} + \dots\dots\dots + \pi_p x_{t-p} + \varepsilon_t \tag{4.9}$$

where x_t = (p x 1) vector of variables

π_0 = (p x 1) matrix of intercept terms

π_i = (p x p) matrices of coefficients

ε_t = (p x 1) vector of error terms

t = 1, 2, ...,T

The second stage involves determining the rank of matrix π by estimating the selected VAR model. There are two test statistics for determining the number of cointegrating vector, namely, maximum eigenvalue and trace statistics, which are illustrated in equation (4.10) and (4.11) respectively. Also, Johansen and Juselius (1990) offer the critical values of these two statistics.

$$\lambda_{\max}(r, r+1) = -T\ln(1-\hat{\lambda}_{r+1}) \tag{4.10}$$

$$\lambda_{trace}(r) = -T\sum_{i=r+1}^{p}\ln(1-\hat{\lambda}_i) \tag{4.11}$$

where $\hat{\lambda}_i$ = estimated values of the characteristic roots

r = rank of matrix

T = number of observations

After the determination of the number of cointegrating vector, an error-correction model can be established by applying the Granger Representation Theorem. According to this theorem, the corresponding error-correction representation of the VAR model as shown in equation (4.9) is presented as equation (4.12).

$$\Delta x_t = \pi_0 + \Gamma_1 \Delta x_{t-1} + \Gamma_2 \Delta x_{t-2} + \ldots\ldots\ldots\ldots\ldots + \Gamma_{p-1}\Delta x_{t-p-1} + \pi x_{t-p} + \varepsilon_t \tag{4.12}$$

Equation (4.12) can be expressed as

$$\Delta x_t = \pi_0 + \sum_{i=1}^{p-1}\Gamma_i \Delta x_{t-i} + \pi x_{t-p} + \varepsilon_t \tag{4.13}$$

where $\Gamma_i = -(I - \pi_1 - \ldots\ldots\ldots - \pi_i)$, for $i = 1,\ldots\ldots\ldots, p-1$

$\pi = -(I - \pi_1 - \ldots\ldots\ldots - \pi_p)$

The rank of π is equal to the number of cointegrating vector. If rank(π) = 0, the variables are not cointegrated and hence, no cointegrating vectors exist. If $0 < \text{rank}(\pi) = r < p$, there are r cointegrating vectors. For the third case, if rank (π) = p, this illustrates that all the variables are stationary.

CHAPTER 5

MODEL SPECIFICATION AND DATA ISSUES

By applying the estimation techniques discussed in chapter four, the effects of exchange rate variability on trade flows of Taiwan are investigated empirically. As mentioned in section 2.2.1 of chapter two, McKenzie (1998) notes that analyzing only the multilateral trade data would weaken the true relationship between the level of trade and the variability of exchange rate. Hence, as well as the multilateral trade flows, the bilateral trade flows of Taiwan with the United States are also analyzed in this study. In this chapter, the theoretical basis for the empirical analysis is introduced first. Then, section two describes the data employed in the analysis.

5.1 Model Specification

In this thesis, the impact of exchange rate volatility on trade flows of Taiwan is examined. The theoretical basis of this empirical study is based on the traditional specifications of the long-run equilibrium export and import demand that are stated in Gotur (1985). The export demand function is illustrated as in equation (5.1). According to the trade theory, income of the trading partners is an important determinant of trade. Also, relative price is another substantial factor that affects Taiwan's exports. In addition to Taiwan's export price, the export price of other foreign competitors must also be considered. Moreover, exchange rate volatility is included in the model for investigating the impact of variability of exchange rate on trade.

$$\ln REX_t = \alpha_0 + \alpha_1 \ln W_t + \alpha_2 \ln\left(\frac{PX}{PXW}\right)_t + \alpha_3 \ln V_t + \varepsilon_t \tag{5.1}$$

where REX_t = export volume of Taiwan; W_t = a scale variable which measures the world income; PX_t = export price index of Taiwan; PXW_t = export price index of the world; V_t = a measure of exchange rate volatility; ε_t = disturbance term.

Many empirical studies have adopted this model in the investigation of the effects of variability of exchange rate, namely, Asseery and Peel (1991), Chowdhury (1993) and Arize (1997). Among this empirical literature, Chowdhury (1993) and Arize (1997) also employ the econometric techniques of cointegration and error-correction modeling, while statistically significant results are yielded in their studies.

Similarly, as shown in equation (5.2), the long-run equilibrium import demand function is also specified in terms of real income of Taiwan, relative price ratio of Taiwan's import price index to the price level of Taiwan and variability of exchange rate. This specification has been favored by several empirical studies, such as Kenen and Rodrik (1986) and Arize (1998).

$$\ln RIM_t = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln\left(\frac{PM}{P}\right)_t + \beta_3 \ln V_t + \varepsilon_t \tag{5.2}$$

where RIM_t = import volume of Taiwan; Y_t = real income of Taiwan, which is measured by Taiwan's real gross national product (GNP); PM_t = import price index of Taiwan; P_t = price level of Taiwan, where the wholesale price index is used as a proxy;[7] V_t = a measure of exchange rate volatility; ε_t = disturbance term.

Instead of the multilateral trade flows, the bilateral trade flows of Taiwan are also analyzed. In this study, Taiwan's bilateral trade with the United States is examined. The functions of exports and imports applied in the bilateral analysis are similar to those employed in the investigation of multilateral trade flows. For the import demand function, the income variable and relative price variable are defined in the same way as those applied in the analysis of multilateral trade flows. For the model of export demand, the income variable is defined by the real income of the United States, instead of the real world income. Moreover, the relative price variable is also expressed in a different way where the price variable is proxied by the ratio of Taiwan's export price index to the price level of the United States.

5.2 Hypothesis of the Signs of Variables

With reference to the trade theory, the level of trade increases with income.

[7] Alternatively, the price level of Taiwan can be measured by the consumer price index. Due to the

It is because of the rise in income will cause consumption increases. Conversely, the demand of traded goods will also rise. Therefore, the expected signs of $\alpha_1, \beta_1, \rho_1$ and γ_1 should be positive. For the export demand function, the relative price variable is measured by the ratio of export price of Taiwan to the world export price. For the demand function of imports, this variable is proxied by the ratio of Taiwan's import price to the price level of Taiwan. This variable reflects the competitiveness of traded goods.[8] One would expect that an increase in relative price ratio would lead to a decline in export or import demand, since a rise in export price relative to the world export price would reduce the export demand. Similarly, an increase in import price relative to the domestic prices would also result in a decline in demand for imports. Hence, the sign of the relative price variable is expected to be negative. Besides, the volatility proxy is also included in the models in order to examine the effects of variability of the exchange rate. It is generally held that the exchange rate volatility would hamper the volume of trade. However, as stated in section 2.1.2 of chapter two, some studies have argued that exchange rate variability may lead to a higher level of trade. Since exchange rate volatility may exert negative or positive impact, the expected sign of this variable is indetermined.

5.3 Data Issues

In this study, quarterly data series over the period 1982Q2 to 1999Q1 is

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limitation of resources, we only employ the wholesale price index as a proxy.

[8] Bailey, Tavlas and Ulan (1986) also state that changes in the relative price ratio are changes in real terms of trade, and also reflecting in three aspects, including the variations in nominal exchange rates, differing rates of inflation among countries and changes in relative prices in each country (between its

applied in order to examine the impact of exchange rate volatility on Taiwan's trade flows. The data is obtained from a variety of sources, such as, IMF's *International Financial Statistics (IFS)* CD-ROM, Taiwan Economic Journal Data Bank, Datastream and statistical yearbooks of Hong Kong and Taiwan. The sources of data and the construction of some variables are described as follows.

For the empirical analysis of multilateral trade flows, the export variable is proxied by the export quantum index of Taiwan, while the import variable is measured by Taiwan's import quantum index. Quarterly data series of export and import quantum indices are obtained from the Taiwan Economic Journal Data Bank.

The scale variable that measures the world income is constructed as the weighted average of the real gross domestic product (GDP) at 1990 constant prices of nine major trading partners of Taiwan.[9] These nine major trading partners include the United States, Japan, West Germany, the United Kingdom, Canada, France, Hong Kong, Singapore and South Korea.[10] The weights for each of the above nine trading partners are computed as exports of Taiwan to each importing country divided by the total exports of Taiwan to the above nine countries.[11] Quarterly data series of the real gross domestic product (GDP) at constant 1990

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non-traded and traded goods). Thus, the real exchange rate in terms of traded goods is also reflected.

[9] It would be better to compute the world income as the weighted average of the index of real gross domestic product (GDP). As the data of real GDP index of some countries is not available, we employ the data series of real GDP (in dollar terms) in our study.

[10] Economic Daily News of Taiwan states that these nine regions and countries are the major trading partners of Taiwan.

[11] The world income is computed as $\sum_i \theta_i Y_i$, $i = 1,2,......,9$, where θ_i = country $i's$ export share in the total, Y_i = real gross domestic product (GDP) of country i.

prices of the nine trading partners, except Hong Kong and Singapore, are extracted from the IMF's *International Financial Statistics (IFS)* CD-ROM, while bilateral trade data of Taiwan with the above nine trading partners are collected from the Taiwan Economic Journal Data Bank. The real gross domestic product (GDP) of Singapore and Hong Kong are obtained from the Datastream and *Hong Kong Monthly Digest of Statistics*, which is published by Hong Kong Census and Statistics Department, respectively. As the data of real gross domestic product (GDP) at 1990 constant prices of some countries is not available in 1999Q1, the sample period of the constructed real world income ends at 1998Q4.

For the demand function of imports, the income variable of Taiwan is proxied by Taiwan's real gross national product (GNP). Data series of real gross national product (GNP) of Taiwan is obtained from the Taiwan Economic Journal Data Bank. Also, all data series of real gross domestic product (GDP) and Taiwan's real gross national product (GNP) are converted to the same currency, therefore, in US dollars.

Besides, the data series of export price index of the world is extracted from the IMF's *International Financial Statistics (IFS)* CD-ROM, while indices of Taiwan's export price, import price and wholesale prices are obtained from the Taiwan Economic Journal Data Bank. The base year of all indices is 1990.

For the investigation of bilateral trade flows of Taiwan with the United States, quarterly data series over the period 1982Q2 to 1999Q1 is also employed. Since the export and import quantum indices of bilateral trade flows are not available, the export variable is computed as deflating the bilateral export value by export price index or export unit value index. Similarly, the import variable is constructed as deflating the bilateral import value by import price index or unit value index of imports.

Bilateral trade data of Taiwan with the United States is collected from the Taiwan Economic Journal Data Bank. As mentioned above, data series of export and import price indices are extracted from the Taiwan Economic Journal Data Bank, while the unit value indices of exports and imports are obtained from the *Industry of Free China*, which is published by the Council for Economic Planning and Development, Executive Yuan, the Republic of China. The base year of all indices is 1990.

For the income variable of the function of exports, quarterly data series of real gross domestic product (GDP) at 1990 constant prices of the United States is collected from the IMF's *International Financial Statistics (IFS)* CD-ROM. The price level of the United States is proxied by the GDP deflator. The GDP deflator of the United States is obtained by dividing the nominal GDP by the real GDP. The data source of the nominal GDP for the United States is as same as that of the real GDP.

Eventually, the proxy for the exchange rate volatility is the conditional variance of Taiwan's real effective exchange rate computed by estimating the data series as an ARCH process. Furthermore, the estimation results are reported in chapter three. In the next chapter, the empirical evidence of the examination of both cases of multilateral and bilateral trade flows of Taiwan will be discussed.

CHAPTER 6

EMPIRICAL EVIDENCE AND ANALYSIS

Based on the theoretical basis that presented in section 5.1 of chapter five, the effects of volatility of exchange rate on both of the multilateral and bilateral trade flows of Taiwan are investigated by applying the econometric techniques of multivariate cointegration and error-correction modeling. The empirical evidence will be reported in this chapter. This chapter is organized as follows. In the first section, the empirical results and analysis of the examination of Taiwan's multilateral trade flows are presented. Then, section two discusses the empirical evidence of the bilateral analysis.

6.1 Empirical Evidence of Investigation of Multilateral Trade Flows

In this section, the empirical evidence of the examination of multilateral trade flows of Taiwan will be analyzed. The estimation period runs from 1982Q2 to 1997Q3, while the sample over the period 1997Q4 to 1999Q1 is kept for forecasting analysis. As mentioned in chapter four, an important step before the cointegration test is checking the order of integration of the variables. The augmented Dickey-Fuller (ADF) test and Phillips and Perron (P-P) test are performed to complete this task. The results of the unit root tests are summarized in Table 2.

Table 2 Results of the ADF Test and P-P Test

Variables	Test Type	Lags	t-statistics of the ADF test	t-statistics of the P-P test
$\ln REX$	τ	7	-0.6186	-2.4477
$\Delta \ln REX$	λ	3	-2.7837*	-14.9648**
$\ln W$	τ	0	-2.4699	-2.5548
$\Delta \ln W$	λ	0	-9.6106**	-11.3543**
$\ln(PX / PXW)$	τ	0	-0.4127	-0.4121
$\Delta \ln(PX / PXW)$	λ	0	-5.8809**	-6.7201**
$\ln RIM$	τ	0	-1.1695	-1.4748
$\Delta \ln RIM$	λ	0	-8.6893**	-7.3586**
$\ln Y$	τ	3	-1.0054	-0.09039
$\Delta \ln Y$	λ	2	-3.1252**	-6.4311**
$\ln(PM / P)$	τ	1	-2.1247	-1.3378
$\Delta \ln(PM / P)$	λ	1	-6.0074**	-7.2390**
$\ln V$	λ	0	-5.1417**	-3.6143**

Note: 1. An asterisk (*) and a double asterisk (**) indicate the statistical significance at the 10% and 5% levels respectively. τ and λ represent with and without trend respectively.

2. REX --- Taiwan's real export volume; W --- real income of the world; PX / PXW --- relative price ratio of Taiwan's export price to the world export price; RIM --- Taiwan's real import volume; Y --- Taiwan's real gross national product (GNP); PM / P --- relative price ratio of Taiwan's import price to the wholesale price index of Taiwan; V --- real effective exchange rate volatility.

With reference to the results of the level of the variables, except that of the exchange rate volatility proxy, neither of the test statistics of the ADF test nor P-P test reject the null hypothesis of nonstationary at the significance level. In contrast, for the first differences of the variables, the test statistics of both types of unit root test exceed the 90 or 95 percent confidence intervals. The results illustrate that these variables are integrated of order one. For the level of exchange rate volatility proxy, both of the ADF test and P-P test yield significant test statistics. This shows that the volatility proxy is I (0).

Instead of testing for order of integration of the variables, the test of Zivot and Andrews (ZA) is used to test for a unit root with existence of one structural break. The results of the ZA test are presented in Table 3. The test statistics reveal that the alternative hypotheses of stationarity with structural change are rejected at the significance level.

Table 3 Results of the ZA Test

	Model A			Model B			Model C		
	t-statistics	Lag order	Break Year	t-statistics	Lag order	Break Year	t-statistics	Lag order	Break Year
Real Exports	-3.8118	4	1985 Q3	-4.6319**	4	1988 Q3	-4.7152	4	1988 Q4
Real Imports	-3.0218	0	1987 Q1	-3.4032	0	1992 Q2	-3.3494	0	1992 Q1

Note: An asterisk (*) and a double asterisk (**) indicate the statistical significance at the 10% and 5% levels respectively.

In this study, the Johansen (1991) maximum likelihood procedure is performed to test for the presence of long-run equilibrium relationship among the variables. As discussed in section 4.3.2 of chapter four, the cointegration analysis begins with the determination of a lag length for the vector autoregression (VAR) model. According to the Schwarz Bayesian Criterion (SBC), the unreported results show that both the models of imports and exports have an optimal lag length of one.

After determining the lag length of the VAR model, the next stage is to examine for the presence of the long-run equilibrium relationship among the variables by employing the Johansen cointegration tests. There are two test statistics, namely, maximum eigenvalue and trace statistics for the determination of the number of the cointegrating vector. For these two test statistics, the null hypothesis is that there are at most r cointegrating vectors. The alternative hypotheses are that there are r+1 and at least r+1 cointegrating vectors for the maximum eigenvalue and trace statistics respectively. Besides, according to chapter six of Enders (1995), if the variables are integrated with different orders, they cannot be cointegrated. Since the exchange rate volatility proxy is I (0), which is different from the order of integration of other variables. Hence, the volatility proxy is not included in the cointegrating vector. The results of the Johansen cointegration tests are illustrated in Table 4.

Table 4 Results of the Johansen Cointegration Tests

	Maximum eigenvalue			Trace statistics		
	$H_0: r=0$ $H_1: r=1$	$r \le 1$ $r=2$	$r \le 2$ $r=3$	$r=0$ $r \ge 1$	$r \le 1$ $r \ge 2$	$r \le 2$ $r \ge 3$
Export Demand Model	27.5754**	8.5647	6.6055	42.7457**	15.1703	6.6055
Import Demand Model	19.3697	12.9506	4.0572	36.3776**	17.0079	4.0572
Critical Values						
95 percent	22.0400	15.8700	9.1600	34.8700	20.1800	9.1600
90 percent	19.8600	13.8100	7.5300	31.9300	17.8800	7.5300

Note: An asterisk (*) and a double asterisk (**) indicate the statistical significance at the 10% and 5% levels respectively.

For the import demand function, the maximum eigenvalue test statistics reveal that the null hypothesis of $r = 0$ cannot be rejected at the significance level. However, the trace statistics show that the null hypothesis of $r = 0$ can be rejected at the 5 percent significance level, while the null hypotheses of $r \le 1$ and $r \le 2$ cannot be rejected. These empirical results illustrate that there exists a long-run equilibrium relationship among the variables.

According to the test statistics of maximum eigenvalue for the export demand function, the null hypothesis of $r = 0$ can be rejected at the 5 percent significance level. In contrast, the hypotheses of $r \le 1$ and $r \le 2$ cannot be rejected. The trace test also yields similar results that the test statistic of the null hypothesis of no cointegrating vector, therefore $r = 0$, exceeds the 95 percent confidence intervals. However, the test results of hypotheses of $r \leq 1$ and $r \leq 2$ are not statistically significant. Overall, the results of the cointegration tests suggest the presence of a cointegrating vector.

The results of the estimated cointegrating vectors of the import and export demand functions are presented in equation (6.1) and (6.2) respectively. The corresponding cointegrating vectors are normalized on real imports and real exports in order to give the economic meanings. This is done by dividing the corresponding cointegrating vectors by the negative of the estimated real import and export coefficients. The long-run equilibrium elasticity of the variables can be obtained by normalizing the cointegrating vectors.

$$\ln RIM_t = 0.6836 \ln Y_t - 1.6769 \ln(\frac{PM}{P})_t + 2.0469 \quad (6.1)$$

$$\ln REX_t = 2.6536 \ln W_t - 0.7778 \ln(\frac{PX}{PXW})_t - 17.3443 \quad (6.2)$$

where RIM = Taiwan's real import volume; Y = Taiwan's real gross national product (GNP); PM / P = relative price ratio of Taiwan's import price to the wholesale price index of Taiwan; REX = Taiwan's real export volume; W = real income of the world; PX / PXW = relative price ratio of Taiwan's export price to the world export price; V = real effective exchange rate volatility.

With reference to equation (6.1), the long-run elasticity of income in the equation of imports has the expected positive sign and is equal to 0.6836. This implies that 1 percent increase in real income of Taiwan will lead to 0.6836 percent rise in imports. Moreover, the long-run elasticity of relative price is –1.6769 and carries the expected negative sign. This high price elasticity can be explained by the effect of import substitution. In fact, the industrialization of Taiwan has fostered the development of the industries which produce substitutes for imports. If import price is relatively higher than the domestic price level, consumers may buy the domestic goods rather than foreign imports. Hence, the response of import demand to changes in relative price ratio of Taiwan's import price to domestic price level is fairly large.

According to the export equation in (6.2), the estimated income elasticity is 2.6536 and displays the expected positive sign. This large income elasticity shows that the exports of Taiwan are highly affected by and dependent on the state of the world economy. Moreover, it is found that the income elasticity of the export demand is far greater than that of the import demand. This reflects that Taiwan's exports grow more rapidly than imports over the estimation period.[12] This finding is supported by recent trade statistics. Figure 1 shows the exports, imports and trade balance of Taiwan over the period 1982 to 1997. This figure reveals that Taiwan has experienced trade surplus over these years.

[12] According to Johnson (1958), under certain conditions, the direction in which the trade balance move over time depends critically on each country's income elasticity of demand for imports and the rest of the world's income elasticity of demand for each country's exports.

Figure 1 Exports, Imports and Trade Balance of Taiwan from 1982 to 1997

Besides, other empirical studies have also yielded large income elasticity in the examination of the export demand function. For instance, Arize (2000) finds that the income elasticity is greater than two in ten out of the 13 equations under estimation and exceeds three in six equations. Riedel (1988) also mentions that whether for developed or developing countries, or for country aggregates or in individual countries, most income elasticities generally lie in the range between two to four.[13] According to the empirical research of Riedel (1988), the estimated income elasticity of Hong Kong's exports of manufactures is greater than four.

Regarding the impact of the relative price ratio of Taiwan's export price to the world export price on the export demand, the estimated price elasticity also has the expected negative sign and is equal to –0.7778. This reflects Taiwan's exports still have the competitive power that for 1 percent drop in export price of Taiwan will cause 0.7778 percent rise in the export demand.

According to the Granger Representation Theorem, the error-correction representation exists if the cointegrating vector is present. The estimated error-correction models for both of the import and export demand function are summarized in Appendix 1 and 2 respectively. As noted, the main focus of this study is investigating the effects of exchange rate variability on Taiwan's trade flows. As the order of integration of the volatility proxy is zero and differs from that of other variables. Thus, it is excluded from the cointegrating vector. Besides, the impact of exchange rate volatility can be found by refering to the estimated error-correction models.

According to the error-correction models, it is found that the estimated elasticity of exchange rate volatility carries negative sign and is statistically significant at the 10 percent and 5 percent significance level for the import and export demand function respectively. These empirical results are consistent with the common notion that variability of exchange rate would exert negative impact on

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[13] As shown in page 140 of Riedel (1988).

trade. With reference to the common hypothesis stated by Sercu (1992)[14], the adverse effects of exchange rate volatility can be explained by the fact that if hedging is costly or impossible, the volatility of exchange rate will impose a higher cost on trade for the risk-adverse traders who suffer from the undiversified exchange rate risk. When the exchange rate risk rises, the expected profits from trade will drop. Hence, the risk-adverse traders will prefer domestic market rather than foreign market. As a result, the volume of trade will decrease. By and large, the statistically significant results of this study demonstrate that exchange rate volatility plays an important role in determining the demand for exports and imports.

For both the export and import demand functions, the one-lagged error term has the expected negative sign and is statistically significant at the 5 percent significance level. This proves that the long-run equilibrium relationship among the variables in each cointegrating equation is valid. Besides, the coefficients of the error term illustrates the average speed at which the import and export volume adjust to the departures from equilibrium conditions in each period. For the import demand model, there are about 41.18 percent of adjustment occurs in each quarter, while the speed of adjustment for the model of exports is only about 26.29 percent in each quarter.

Lastly, the observations over the period 1997Q4 to 1999Q1 are kept for forecasting analysis to check for the appropriateness of the estimated models. The forecasting results of the estimated models of imports and exports are presented in

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[14] As shown in page 579 of Sercu (1992).

Appendix 3 and 4 respectively. In particular, as the sample of the world income is only available from 1982Q2 to 1998Q4, the forecasting period for the export model ranges from 1997Q4 to 1998Q4. For the forecasting analysis, the forecast growth rates are computed and compared with the actual growth rates. Moreover, the mean square forecasting errors have also been computed. With reference to the comparison of the actual and forecast growth rates of the import model, it is found that the estimated model can roughly capture the trend of the growth rates, except the drop of growth rate in the first quarter in 1998. Similarly, for the export model, the comparison shows that the model cannot predict the changes of growth rates in 1998Q1 and 1998Q2. In fact, the unsatisfactory forecasting results may be due to the occurrence of the Asian financial crisis in the forth quarter in 1997. Since the estimation of the models mainly based on the historical realizations, it may not be possible to predict the changes of growth rates after the happening of the crisis.

6.2 Empirical Evidence of Investigation of Bilateral Trade Flows

Instead of the analysis of multilateral trade flows, bilateral trade flows of Taiwan with the United States are also investigated. As mentioned in chapter one, the United States has been the largest trading partner of Taiwan since the early 1950s. The bilateral trade between Taiwan and the United States makes up the biggest proportion of Taiwan's total trade volume.

For the bilateral analysis, the methodology of estimation is similar to that applied in the investigation of multilateral trade flows. The estimation period also runs from 1982Q2 to 1997Q3, while the observations over the period 1997Q4 to 1999Q1 are kept for forecasting analysis. The differences of the export and import demand models employed in the investigation of bilateral trade flows from those of the multilateral trade flows analysis have been discussed in chapter five. The empirical evidence is analyzed as follows.

Before the cointegration test, the orders of integration of the variables are tested by the ADF test and P-P test. The empirical results are shown in Table 5. In particular, the data series of the volatility proxy applied in the cases of multilateral and bilateral trade flows are the same. As stated in the unit root test results in the last section, the exchange rate volatility proxy is I (0). Besides, the test statistics of the level of all variables suggest that the null hypothesis of a unit root cannot be rejected at the 5 percent significance level. However, the test statistics of the first differences of all variables exceed the 95 percent confidence intervals. This illustrates that these variables are integrated of order one.

Table 5 Results of the ADF Test and P-P Test

Variables	Test Type	Lags	t-statistics of the ADF test	t-statistics of the P-P test
$\ln UEX$	τ	4	-2.5368	-2.5655
$\Delta \ln UEX$	λ	3	-3.1754**	-18.1184**
$\ln UGDP$	τ	2	-3.0738	-1.1832
$\Delta \ln UGDP$	λ	0	-4.9351**	-3.3105**
$\ln UP$	τ	1	-0.5235	0.09042
$\Delta \ln UP$	λ	0	-4.7525**	-6.3912**
$\ln UIM$	τ	0	-1.6299	-1.9065
$\Delta \ln UIM$	λ	0	-7.4935**	-8.2592**
$\ln Y$	τ	3	-1.0054	-0.09039
$\Delta \ln Y$	λ	2	-3.1252**	-6.4311**
$\ln(PM/P)$	τ	1	-2.1247	-1.3378
$\Delta \ln(PM/P)$	λ	1	-6.0074**	-7.2390**
$\ln V$	λ	0	-5.1417**	-3.6143**

Note: 1. An asterisk (*) and a double asterisk (**) indicate the statistical significance at the 10% and 5% levels respectively. τ and λ represent with and without trend respectively.
2. UEX --- Taiwan's real exports to the United States; $UGDP$ --- real gross domestic product (GDP) of the United States; UP --- relative price ratio of Taiwan's export price to the GDP deflator of the United States; UIM --- Taiwan's real imports from the United States; Y --- Taiwan's real gross national product (GNP); PM/P --- relative price ratio of Taiwan's import price to the wholesale price index of Taiwan; V --- real effective exchange rate volatility.

Moreover, the ZA test is also performed to test for a unit root with presence of one structural break and the results are presented in Table 6. The findings show that the null hypothesis is rejected at the significance level. Hence, dummy variables are included in the models to capture the structural change.

Table 6 Results of the ZA Test

	Model A			Model B			Model C		
	t-statistics	Lag order	Break Year	t-statistics	Lag order	Break Year	t-statistics	Lag order	Break Year
Real Exports to the USA	-6.0361**	4	1985 Q4	-7.0518**	4	1988 Q3	-7.9501**	4	1989 Q3
Real Imports from the USA	-5.1334**	0	1987 Q1	-3.3289	0	1989 Q2	-5.3015**	1	1987 Q3

Note: An asterisk (*) and a double asterisk (**) indicate the statistical significance at the 10% and 5% levels respectively.

After testing for the unit root and structural change, the Johansen (1991) maximum likelihood procedure is performed to test for the long-run equilibrium relationship among the variables. For the determination of the lag length for the VAR models, the unreported results illustrate that the VAR model of the export demand has an optimal lag length of five and the model for the import demand has the lag length as one.

The presence of cointegrating vector is examined by applying the Johansen likelihood ratio tests. The test results are summarized in Table 7. With reference to the empirical results, the null hypothesis of $r = 0$ for the trace test can be rejected at the significance level for both the export and import demand models. In contrast, the trace statistics of hypotheses of $r \leq 1$ and $r \leq 2$ do not exceed the 95 percent confidence intervals. For the maximum eigenvalue test, similar results are also obtained. The null hypothesis of $r = 0$ is well rejected at the significance level, but the null hypotheses of $r \leq 1$ and $r \leq 2$ cannot be rejected. In sum, these results support that there exists a long-run equilibrium relationship among the variables for both cases.

Table 7 Results of the Johansen Cointegration Tests

	Maximum eigenvalue statistics			Trace statistics		
	$H_0: r=0$ $H_1: r=1$	$r \leq 1$ $r=2$	$r \leq 2$ $r=3$	$r=0$ $r \geq 1$	$r \leq 1$ $r \geq 2$	$r \leq 2$ $r \geq 3$
Export Demand Model (USA)	42.0906**	14.6431*	0.8392	57.5729**	15.4823	0.8392
Import Demand Model (USA)	30.1738**	13.1738	0.6549	44.0025**	13.8288	0.6549
Critical Values						
95 percent	22.0400	15.8700	9.1600	34.8700	20.1800	9.1600
90 percent	19.8600	13.8100	7.5300	31.9300	17.8800	7.5300

Note: An asterisk (*) and a double asterisk (**) indicate the statistical significance at the 10% and 5% levels respectively.

Equation (6.3) and (6.4) present the estimated cointegrating vectors of the export and import demand function respectively. Similar to the analysis of multilateral trade flows, the cointegrating vectors are normalized in order to give the economic meanings.

$$\ln UEX_t = 2.0464 \ln UGDP_t - 1.0983 \ln UP_t - 15.4294 \quad (6.3)$$

$$\ln UIM_t = 0.9607 \ln Y_t - 1.1056 \ln (PM / P)_t - 2.6971 \quad (6.4)$$

where UEX --- Taiwan's real exports to the United States; $UGDP$ --- real gross domestic product (GDP) of the United States; UP --- relative price ratio of Taiwan's export price to the GDP deflator of the United States; UIM --- Taiwan's real imports from the United States; Y --- Taiwan's real gross national product (GNP); PM / P --- relative price ratio of Taiwan's import price to the wholesale price index of Taiwan; V --- real effective exchange rate volatility.

As demonstrated in equation (6.3), the income elasticity of demand for Taiwan's exports is as high as 2.0464 and has the expected positive sign. This great income elasticity implies that the response of the export demand to the changes in income of the United States is large. This also reflects that the export demand is highly affected by the income of the United States. Furthermore, the long-run income elasticity of the import equation also carries the expected positive sign and is less than that of the export equation. This empirical evidence reveals that Taiwan has experienced trade surplus for the bilateral trade with the United States. This finding is supported by the trade statistics. Figure 2 shows the exports, imports and trade balance of the bilateral trade between Taiwan and the United States from 1982 to 1997. This figure illustrates that Taiwan has run a trade surplus with the United States during these years.

Figure 2 Exports, Imports and Trade Balance of the Bilateral Trade between Taiwan and the U.S.A. from 1982 to 1997

For the impact of export price on the demand for exports, the price elasticity carries the expected negative sign and is greater than the unity. This implies the competition power of Taiwan's exports is quite high, for 1 percent decrease in export price will cause 1.0983 percent rise in export demand from the United States. Regarding the import equation, the price elasticity also displays the expected negative sign and is equal to –1.1056. This suggests that the response of import demand to changes in import price is quite large.

After examining for the presence of the cointegrating vector, the error-correction models can also be established. The error-correction models for the export and import equation are summarized in Appendix 5 and 6 respectively. In particular, this study attempts to analyze the impact of exchange rate variability on trade. As stated in the last section, although the volatility proxy is not included in the cointegrating vector, the effects of variability of exchange rate can be found according to the estimated error-correction models. The results show that the elasticity of exchange rate volatility has negative sign and is statistically significant for the import demand model. This finding is consistent with the common argument that exchange rate volatility would adversely affect trade flows. Specifically, for the model of export demand, the elasticity of exchange rate volatility is positive and also statistically significant. Indeed, this empirical evidence is not surprising that the exchange rate volatility may lead to a higher level of trade. This point of view is supported by some theoretical literature, such as De Grauwe (1988). As stated by De Grauwe (1988), if the traders are sufficiently risk-adverse, the expected marginal utility of trade revenue will increase with the rise in exchange rate volatility. This will cause the traders to raise the level of trade. Since the very risk-adverse traders may worry about that a rise in exchange rate risk will lead to a large decline in revenue, they will increase the foreign trade. In contrast, for the traders who are less risk-adverse, they consider the profits from trade are less attractive due to the exchange rate risk. Hence, they will decrease the level of trade when exchange rate variability increases. In sum, if the income effect dominates over the substitution effect, it is possible that exchange rate volatility can exert positive impact on trade.

Besides, the one-lagged error term is statistically significant and displays the expected negative sign for the estimated models. This evidence confirms the validity of the cointegrating relationship among the variables. The dummy variables that capture the structural change are also statistically significant.[15] Furthermore, dynamics of the export demand model illustrate that changes in income of the United States and relative price have short-run effects as well as long-run impact on exports.

Similar to the investigation of multilateral trade flows, observations run from 1997Q4 to 1999Q1 are applied in the forecasting analysis. With reference to the forecasting results shown in appendix 7 and 8, it is found that the estimated models can approximately capture the signs and trend of the growth rates.

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[15] For the import demand model of the bilateral analysis, the trend dummy variable is dropped because this variable is not statistically significant. Besides, the estimation results are not greatly affected after dropping the trend dummy variable.

CHAPTER 7

CONCLUSION

After the inception of flexible exchange rates in 1973, there has been a substantial fluctuation in most of the major exchange rates. The issue of whether exchange rate volatility would discourage trade has aroused the interests of numerous researchers and policy makers. In this thesis, we attempt to provide additional empirical evidence. Applying the econometric techniques of multivariate cointegration and error-correction modeling, this study analyzes the effects of exchange rate variability on trade flows of Taiwan over the period 1982Q2 to 1997Q3. Moreover, an ARCH model is used to generate the proxy for exchange rate volatility. Besides the multilateral trade flows, bilateral trade of Taiwan with the United States is also examined. The empirical evidence of this thesis is summarized as follows.

In this study, we employ the unit root tests (the ADF test and P-P test) to examine the stationarity of the variables. The results illustrate that all variables are nonstationary, except the volatility proxy. These findings suggest that the implicit assumption of data stationarity applied in many studies should be incorrect and the ignorance of the nonstationarity of the data series may lead to spurious inferences.

As the proxy for exchange rate volatility is I(0) and has the order of integration differs from other variables, it is not included in the cointegrating vector. Furthermore, the results of the Johansen cointegration tests reveal the presence of the long-run equilibrium relationship among the variables (trade variables, real income and relative prices) in all cases.

For the analysis of multilateral trade flows, the estimated error-correction models show that exchange rate volatility exerts a significantly negative impact on both Taiwan's export and import flows. On the other hand, the evidence from the investigation of bilateral trade flows between Taiwan and the United States is less consistent. It is found that variability of exchange rate has adverse effects on the import flows, whilst the impact on the export flows is positive.

Although statistically significant results are obtained in this study, our empirical analysis is limited in some aspects. As noted by McKenzie (1998), the influence of exchange rate volatility does differ between countries and traded good sectors. The examination of aggregate trade data may weaken the true relationship between exchange rate volatility and trade flows. Therefore, it would be more appropriate to employ the trade data that is sufficiently disaggregated in the analysis, such as sectoral trade data. As the sectoral trade data is not sufficient for rigid study, especially for the bilateral trade analysis, aggregate trade data is employed instead. Hence, our results may be biased to some extent.

In general, majority of our findings suggest that exchange rate volatility would hamper trade flows. For the prospect of international trade, it is desirable for the government to lower the variability of exchange rate by the intervention in exchange markets. However, the domestic economy may suffer damage from retaliation and speculative attacks. The government should thus take the strategy of intervention in exchange markets with great caution.

APPENDIX 1

Results for Error-Correction Model of the Import Demand Function (Multilateral Trade Flows of Taiwan)

$$\ln RIM_t = -0.4118\,(\ln RIM - 0.6836\ln Y + 1.6769\ln(\frac{PM}{P}) - 2.0469)_{t-1} - 0.001877\ln V_t$$

$$(-4.6616)^{**} \qquad\qquad\qquad\qquad\qquad\qquad (-1.8274)^{*}$$

Diagnostic Tests

R-Squared = 0.2687

R-Bar-Squared = 0.2563

F-stat. F (1, 59) = 21.6772 [0.000]

DW-statistic = 2.0720

Serial Correlation CHSQ (4) = 0.7373 [0.947]

Heteroscedasticity CHSQ (1) = 0.4067 [0.524]

Note: 1. An asterisk (*) and a double asterisk (**) indicate the statistical significance at 10% and 5% levels respectively. Figures in parentheses are t-statistics.

2. RIM --- Taiwan's real import volume; Y --- Taiwan's real gross national product (GNP); PM / P --- relative price ratio of Taiwan's import price to the wholesale price index of Taiwan; V --- real effective exchange rate volatility.

APPENDIX 2

Results for Error-Correction Model of the Export Demand Function (Multilateral Trade Flows of Taiwan)

$$\Delta \ln REX_t = -0.2629(\ln REX - 2.6536 \ln W + 0.7778 \ln(\frac{PX}{PXW}) + 17.3443)_{t-1} - 0.02024 \ln V_t$$

(-2.9780)** (-3.2739)**

Diagnostic Tests

R-Squared = 0.1322

R-Bar-Squared = 0.1174

F-stat. F (1, 59) = 8.9839 [0.004]

DW-statistic = 2.2553

Serial Correlation CHSQ (4) = 5.8159 [0.213]

Heteroscedasticity CHSQ (1) = 0.1968 [0.657]

Note: 1. An asterisk (*) and a double asterisk (**) indicate the statistical significance at 10% and 5% levels respectively. Figures in parentheses are t-statistics.

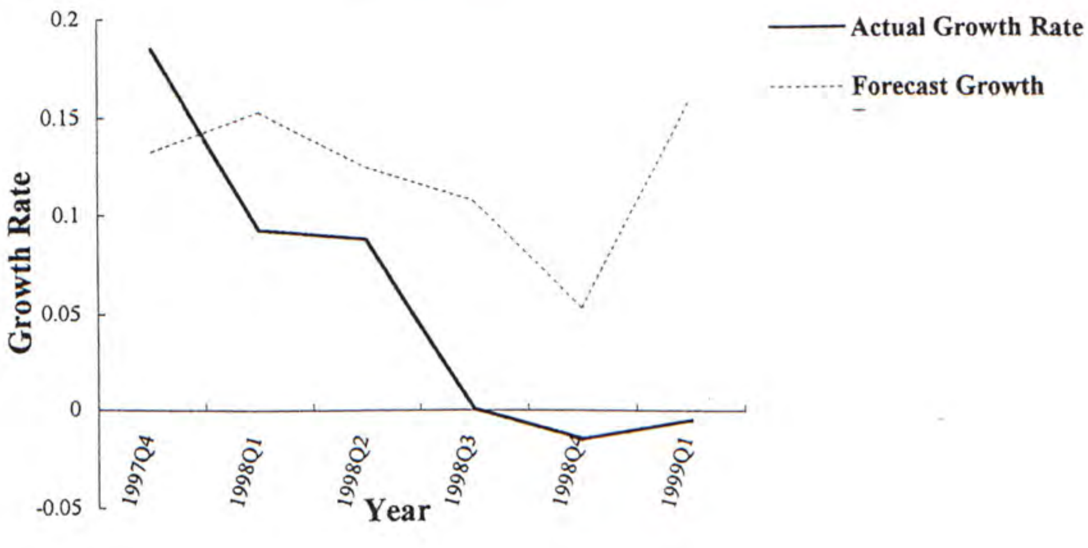
2. REX --- Taiwan's real export volume; W --- real income of the world; PX / PXW --- relative price ratio of Taiwan's export price to the world export price; V --- real effective exchange rate volatility.

APPENDIX 3

Growth Rate Comparison of Taiwan's Real Import Volume

Year	Actual Growth Rate	Forecast Growth Rate
1997Q4	0.1849	0.1324
1998Q1	0.09167	0.1525
1998Q2	0.08730	0.1249
1998Q3	0.0007628	0.1077
1998Q4	-0.01418	0.05312
1999Q1	-0.004566	0.1592
Mean Square Error	0.008442	

Figure 3 Actual and Forecast Growth Rates of Taiwan's Real Import Volume

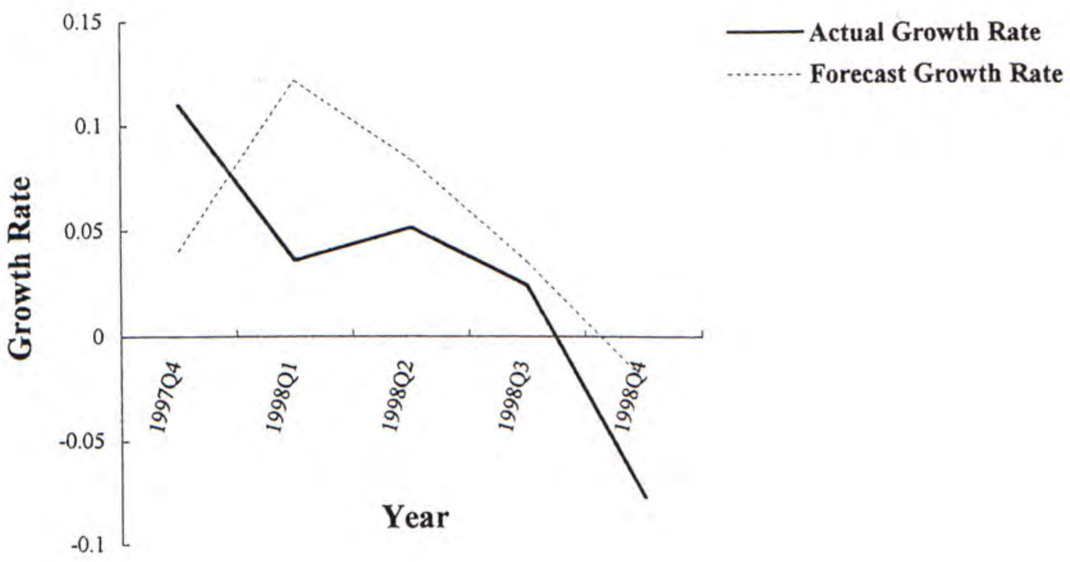


APPENDIX 4

Growth Rate Comparison of Taiwan's Real Export Volume

Year	Actual Growth Rate	Forecast Growth Rate
1997Q4	0.1102	0.04042
1998Q1	0.03636	0.1226
1998Q2	0.05217	0.08470
1998Q3	0.02459	0.03582
1998Q4	-0.07634	-0.02099
Mean Square Error	0.003311	

Figure 4 Actual and Forecast Growth Rates of Taiwan's Real Export Volume



Appendix 5

Results for Error-Correction Model of the Export Demand Function (Bilateral Trade Flows between Taiwan and the United States)

$$\Delta \ln UEX_t = \underset{(2.6577)^{**}}{0.3906} \Delta \ln UEX_{t-1} - \underset{(-1.8918)^{*}}{2.8490} \Delta \ln UGDP_{t-1} - \underset{(-0.04307)}{0.02009} \Delta \ln UP_{t-1}$$

$$+ \underset{(1.2277)}{0.1483} \Delta \ln UEX_{t-2} - \underset{(-0.2872)}{0.4100} \Delta \ln UGDP_{t-2} - \underset{(-0.2912)}{0.1382} \Delta \ln UP_{t-2}$$

$$+ \underset{(1.5401)}{0.1475} \Delta \ln UEX_{t-3} - \underset{(-0.3013)}{0.3989} \Delta \ln UGDP_{t-3} - \underset{(-0.5483)}{0.2584} \Delta \ln UP_{t-3}$$

$$+ \underset{(7.3016)^{**}}{0.6940} \Delta \ln UEX_{t-4} - \underset{(-3.0819)^{**}}{4.1102} \Delta \ln UGDP_{t-4} + \underset{(2.5497)^{**}}{1.1955} \Delta \ln UP_{t-4}$$

$$- \underset{(-4.3092)^{**}}{0.6885} (\ln UEX - 2.0464 \ln UGDP + 1.0983 \ln UP + 15.4294)_{t-1}$$

$$+ \underset{(2.4093)^{**}}{0.01745} \ln V_t - \underset{(-4.9173)^{**}}{0.1556} DYUEX - \underset{(-3.7520)^{**}}{0.009316} DTUEX$$

Diagnostic Tests

R-Squared = 0.8352

R-Bar-Squared = 0.7749

F-stat. F (15, 41) = 13.8546 [0.000]

DW-statistic = 2.1713

Serial Correlation CHSQ (4) = 5.1516 [0.272]

Heteroscedasticity CHSQ (1) = 0.03789 [0.846]

Note: 1. An asterisk (*) and a double asterisk (**) indicate the statistical significance at 10% and 5% levels respectively. Figures in parentheses are t-statistics.

2. UEX --- Taiwan's real exports to the United States; $UGDP$ --- real gross domestic product (GDP) of the United States; UP --- relative price ratio of Taiwan's export price to the GDP deflator of the United States; V --- real effective exchange rate volatility; $DYUEX$ --- level dummy variable; $DTUEX$ --- trend dummy variable.

APPENDIX 6

Results for Error-Correction Model of the Import Demand Function (Bilateral Trade Flows between Taiwan and the United States)

$$\Delta \ln UIM_t = -0.6752(\ln UIM - 0.9607\ln Y + 1.1056\ln(\frac{PM}{P}) + 2.6971)_{t-1} - 0.008572\ln V_t$$
$$\qquad (-5.9963)^{**} \qquad\qquad\qquad\qquad\qquad\qquad\qquad (-3.3322)^{**}$$

$$+0.1596 DYUIM$$
$$(4.3032)^{**}$$

Diagnostic Tests

R-Squared = 0.3803

R-Bar-Squared = 0.3589

F-stat. F (2, 58) = 17.7938 [0.000]

DW-statistic = 1.9151

Serial Correlation CHSQ (4) = 1.6171 [0.806]

Heteroscedasticity CHSQ (1) = 1.5290 [0.216]

Note: 1. An asterisk (*) and a double asterisk (**) indicate the statistical significance at 10% and 5% levels respectively. Figures in parentheses are t-statistics.

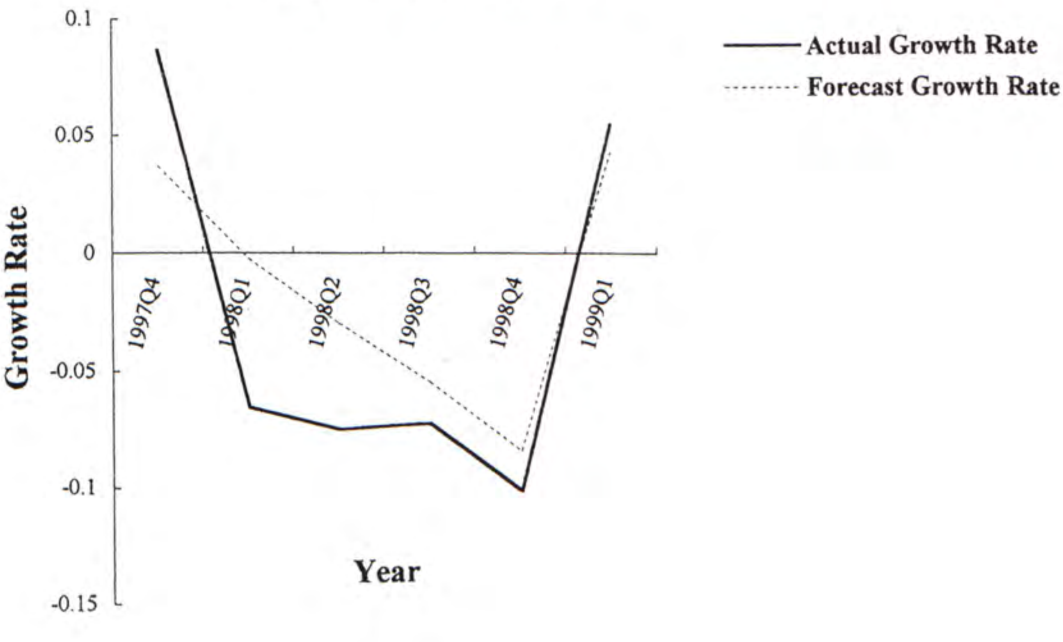
2. UIM --- Taiwan's real imports from the United States; Y --- Taiwan's real gross national product (GNP); PM/P --- relative price ratio of Taiwan's import price to the wholesale price index of Taiwan; V --- real effective exchange rate volatility; $DYUIM$ --- level dummy variable.

APPENDIX 7

Growth Rate Comparison of Taiwan's Real Exports to the United States

Year	Actual Growth Rate	Forecast Growth Rate
1997Q4	0.08670	0.03714
1998Q1	-0.06531	-0.002363
1998Q2	-0.07494	-0.03007
1998Q3	-0.07271	-0.05520
1998Q4	-0.1012	-0.08440
1999Q1	0.05503	0.04307
Mean Square Error	0.001527	

Figure 5 Actual and Forecast Growth Rates of Taiwan's Real Exports to the United States

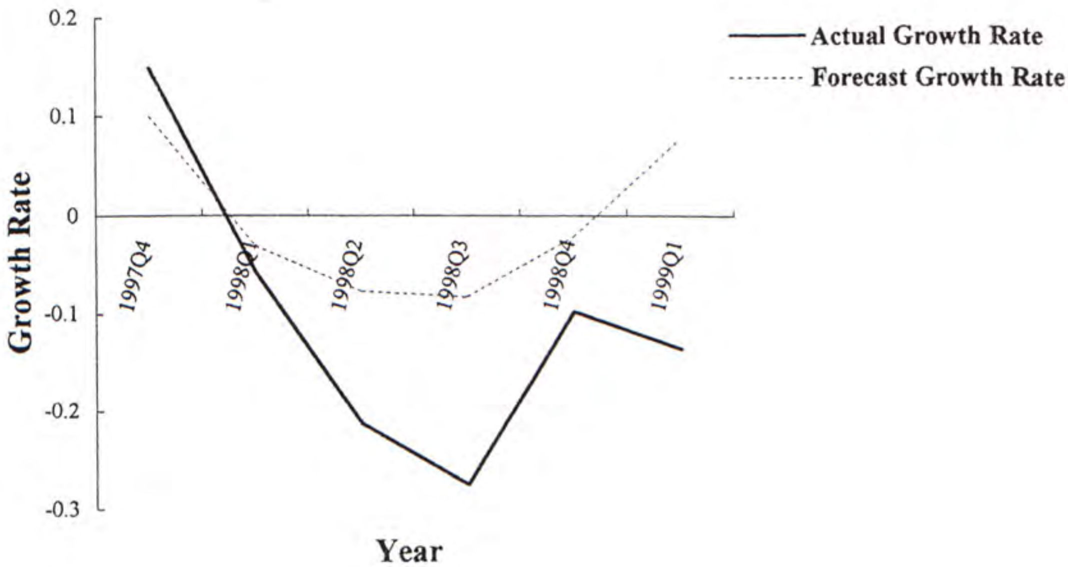


APPENDIX 8

Growth Rate Comparison of Taiwan's Real Imports from the United States

Year	Actual Growth Rate	Forecast Growth Rate
1997Q4	0.1495	0.1005
1998Q1	-0.05720	-0.03075
1998Q2	-0.2101	-0.07697
1998Q3	-0.2724	-0.08316
1998Q4	-0.09759	-0.02167
1999Q1	-0.1354	0.07817
Mean Square Error	0.01800	

Figure 6 Actual and Forecast Growth Rates of Taiwan's Real Imports from the United States



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